Distribution and Biomass of the Red Sea Cucumber, *Parastichopus californicus* (Stimpson), Found in Inlets of North British Columbia

K. E. Cripps and A. Campbell

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
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DISTRIBUTION AND BIOMASS OF THE RED SEA CUCUMBER, *Parastichopus californicus* (STIMPSON), FOUND IN INLETS OF NORTH BRITISH COLUMBIA

by

K. E. Cripps[1] and A. Campbell[2]

Fisheries and Oceans Canada

Science Branch, Pacific Region

Pacific Biological Station

Nanaimo, British Columbia

V9R 5K6

[1]Kitasoo Fisheries Program
P.O. Box 001, Klemtu, B. C., V0T 1L0, Canada

[2]Author to whom all correspondence should be sent.

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ABSTRACT

Cripps, K. E. and A. Campbell. 2000. Distribution and biomass of the red sea cucumber, *Parastichopus californicus* (Stimpson), found in inlets of north British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2300: 14 p.

Population numbers and harvestable biomass of the sea cucumber, *Parastichopus californicus* (Stimpson) were surveyed, within a depth range of 0 to 15.24 m chart datum in six inlets of the north coast of British Columbia. The estimated mean split-weight biomass per km of shoreline ranged from 2.8 to 6.4 t km^{-1}. Sea cucumbers were found most frequently on hard complex substrates and least frequently on soft substrates. At depths surveyed, sea cucumbers were most abundant in depths between 1 to 2 m below which densities generally declined with depth. Drained eviscerated weight varied between survey locations, reflecting different population size structures, however, the percentage of perivisceral fluids, muscle, and skin, in relation to total weight, were similar between areas.

Key words: Red Sea Cucumber, *Parastichopus californicus*, biomass, distribution

RÉSUMÉ

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Les auteurs ont étudié l'effectif de la population et la biomasse exploitable de l'holothurie du Pacifique *Parastichopus californicus* (Stimpson) dans une plage de profondeur comprise entre 0 et 15,24 m selon le zéro hydrographique, dans six bras de mer de la côte nord de la Colombie-Britannique. La biomasse moyenne, en fonction du poids fendu, par kilomètre de littoral est estimée entre 2,8 et 6,4 t km^{-1}. Les holothuries se trouvent plus souvent sur des substrats complexes durs que sur des substrats mous. Aux profondeurs d'étude, les holothuries étaient plus abondantes entre 1 et 2 m, après quoi on observait en général une diminution de la densité en fonction de la profondeur. Le poids égoutté éviscéré variait entre les stations d'étude, ce qui montre l'existence de diverses structures de taille dans la population; cependant, le pourcentage de liquide périviscéral, de muscle et de tégument, par rapport au poids total, était semblable entre les zones étudiées.

Mots clés : Holothurie du Pacifique, *Parastichopus californicus*, biomasse, distribution

INTRODUCTION

The red sea cucumber, *Parastichopus californicus* (Stimpson), is a common holothuroid in the shallow subtidal coastal areas from the Gulf of Alaska to Baja California (Brumbaugh 1980), and provides for small commercial dive fisheries in California, Washington, British Columbia, and Alaska (Sloan 1985, 1986, Imamura and Kruse 1990, Conand and Byrne 1993, Woodby et al. 1993, Bradbury et al. 1998). In British Columbia (B.C.), the sea cucumber fishery (using scuba) began in 1980, annual landings (eviscerated drained weight) increased to a maximum of 704 t in 1988, but thereafter landings were reduced under a precautionary arbitrary quota to 276.2 t, valued at about Can $1.0 million, in 1998 (Heizer and Thomas 1997, Rogers and Parker 1999). Management of the commercial fishery in B.C. included limited entry, individual license quotas, closed fishing areas and seasons. Biological information and estimates of density and biomass are important for the sustainable management of fisheries resources. Recent studies on the biology of *P. californicus*, a benthic detritus feeder (Cameron and Fankboner 1984, Penry 1989), have reported on reproduction, development, and recruitment (Cameron and Fankboner 1986, 1989, Sloan 1986, McEuen 1987, 1988, Smiley 1988). To date, however, there has been little quantitative field assessment of *P. californicus* abundance in B.C.

The objectives of this paper were to use dive surveys to estimate the population abundance, size structure and biomass of red sea cucumbers, and to relate *P. californicus* density with depth and substrate type in the shallow subtidal areas of some inland channels of north B.C.

MATERIALS AND METHODS

SAMPLING

The six areas chosen for survey were Griffin Pass, Sheep Pass, Alexander Inlet, Meyers Passage, Tolmie Channel, and Green Inlet (Fig. 1). One hundred and eighty two transects were randomly placed within the survey areas between 1993 and 1996 (Table 1). Transects, the primary sampling unit, were made up of a cluster or variable number of sampling units. Each transect was 4m wide and variable in length depending on the slope within the sampling depth range of 0 to 15.24 m chart datum. The secondary sampling unit was a 20 m^2 quadrat, which consisted of two 10 m^2 (2 x 5 m) quadrats, each sampled by one of the two divers. Lead line, marked every 5 m, was deployed perpendicular to the isolepths to a depth of approximately 15.24 m below chart datum. Divers, equipped with a 2 m bar, swam from deep to shallow along either side of the transect line recording the number of emergent sea cucumbers, substrate type, and dominant algal cover at 5 m intervals. The dive team also recorded the bearing and the depth at the start of each transect. Each transect was surveyed from deep to shallow to prevent the displacement of sea cucumbers into deeper quadrats. All kelp, starfish and debris were removed from the quadrat to ensure sea cucumbers were detected, however, caution was exercised to ensure sea cucumbers residing on algal material were not inadvertently discarded. After being

enumerated, a sea cucumber was removed from the quadrat to ensure individuals were not counted multiple times. Sea cucumbers often cluster in between boulders and in crevasses, therefore divers had to remove the outer animals to observe inner animals. Boulders were not moved to search for cryptic individuals.

All depth recordings were converted to depth at datum. The surveys were conducted within the depth range of 0 to 15.24 m datum for safety reasons. Deeper dives would reduce the number of transects the divers could safely swim per day. As well, this depth range is generally where the commercial sea cucumber fishery is executed.

SHORELINE LENGTH

Shoreline lengths, in metres, were derived from Compugrid GIS with basemaps that were digitized from Canadian Hydrographic Service nautical charts. The surveyed bed lengths were measured as a continuous line along the shoreline of the chart; small indentations of the shoreline were ignored. Both sides of the shoreline were measured for all areas, except for portions where depths spanning the channel or fiord were less than or equal to 15.24 m below chart datum. This procedure was repeated three times and standard errors of the measurements were found to be about 1% of the estimated mean shoreline length.

MEAN WEIGHTS

Samples of red sea cucumbers were collected from randomly selected sites within each survey area. Between 144 and 585 animals were collected from several transects in each survey area. Sea cucumbers were transported to a processing plant, where at approximately five hours post harvest each animal was weighed for round weight, sliced longitudinally and allowed to drain for at least one minute before being weighed for "split" (drained eviscerated) weight. Subsequently, sliced sea cucumbers were processed by a trained fish plant processor and the skin and muscle were weighed separately for each animal. Only split weights were recorded for the 1993 survey in Sheep and Griffin Pass.

BIOMASS AND DENSITY CALCULATIONS

An inflation estimator method was used to estimate sea cucumber population size and biomass. This method used the product of the mean number of sea cucumbers per metre of shoreline (estimated from the transects) and shoreline length of the bed in metres. Methods used in this study are similar to that proposed by Woodby et al. (1993), but differ in the analytical approach. A bootstrap program, written in S-Plus, was used to generate distribution free estimates of mean and 95% confidence intervals (Efron and Tibshirani 1993) for sea cucumber

number/metre of shoreline and biomass. For each mean number/m (h_i), calculated by randomly resampling each set of the transects per survey n times with replacement, a corresponding population number (P_i) and biomass (B_i) was calculated as:

$$P_i = h_i\,(L + se(L)\,z) \tag{1}$$

$$B_i = P_i\,(W + se(w)\,z) \tag{2}$$

where L is the shoreline length of the bed in metres, se(L) is the estimated standard error of the shoreline length, W is the estimated mean split weight, se(w) is the estimated standard error of the weight and z is a random number from a standard normal population, calculated by the Box Muller method (Press et al. 1986). This procedure was repeated a 1000 times and the overall estimated mean current population number (P_c) and biomass (B_c) were calculated by summing all the B_i's or P_i's and dividing by 1000.

The sea cucumber density in relation to depth and density substrate categories was also examined by using the bootstrap method. Sea cucumber mean numbers/m^2 were calculated from all 20 m^2 quadrats per transect for each depth category (at 1.5 metre intervals from 0 to 15 m) and substrate type (1 = smooth bedrock, 2 = complex bedrock, boulders and/or cobbles, 3 = mixed hard/soft with hard substrate dominant, 4= mainly soft substrate with little or no hard substrates). The overall mean densities and 95 % confidence intervals for each depth zone and for each substrate type were obtained by bootstrapping the mean densities from all transects in a particular category.

In each of the surveyed areas, there was no significant difference (Mann-Whitney test, $p>0.05$) in the numbers/m recorded between individual divers, so data for all divers were combined.

RESULTS

WEIGHT CHARACTERISTICS

The mean round weight ranged from 893.9 g to 365.5 g between areas (Table 1). The mean split weigh for sea cucumbers collected from Sheep Passage and Green Inlet were lower than animals sampled from other areas (Table 1). There were no differences (Mann-Whitney test, $p >0.05$) in sea cucumber mean split wet weight biomass between Autumn 1993 and Spring 1994 for both Sheep and Griffin Passages, therefore the data were combined (Table 1). The percentage of perivisceral fluid weight ranged between 45 % and 58 % of the round weight. The percentage

of muscle of the total split weight was similar (26-28 %) between locations. Few (< 5%) of the sea cucumbers sampled during the fall possessed viscera compared to those sampled in the spring when the majority of the animals possessed viscera.

BIOMASS AND DENSITY ESTIMATES

The estimated mean number of animals/m or shoreline ranged from 9.71 in Alexander Inlet to 20.34 in Tolmie Channel (Table 2). Biomass was found to be lowest in Griffin Pass (2.83t/km) and highest in Tolmie Channel (6.38 t/km) (Table 2).

Sea cucumbers were distributed throughout all study areas except in locations where large volumes of fresh water entered the marine environment on a continuous basis. Highest densities of sea cucumbers were found in 1-2 m depths with lower densities found at all other depths surveyed (Fig. 2). Sea cucumber densities were highest on hard complex substrates, whereas densities were lowest on soft substrates (Fig. 3).

DISCUSSION

This study represents a first attempt to obtain fisheries independent data necessary for estimating population size and biomass for use in estimating quotas for the sea cucumber fishery in B. C. The estimated mean numbers of red sea cucumbers per metre of shoreline (9.71 to 20.34) in central British Columbia were similar for those reported from Alaska (Woodby et al. 1993, Larson et al. 1995). However, estimated mean densities in our dive survey were higher than those reported from Washington using video methods (Bradbury et al. 1998) and from Barlow Cove, southeast Alaska, using a manned submersible (Zhou and Shirley 1996).

Variation in the estimated mean weights probably reflected the population size structure between the different survey locations. Our results are similar to the total mean weight of drained eviscerated estimated for *P. californicus* (0.28 kg) in Washington by Bradbury et al. (1998). Small juvenile sea cucumbers less than 26 g (split or drained eviscerated weight) were not encountered during this study. Whether the lack of small juveniles was due to their cryptic nature or lack of recruitment was unknown. The percentage of perivisceral fluids in the sea cucumbers, and the percentage of muscle and skin of the split weight was constant between survey locations. The low percentage of perivisceral fluids in the Green Inlet sample was likely due to heat induced mortality that occurred during transport back to the laboratory.

Speculation by fishermen, and evidence in the literature (Mottet 1976), suggested a fall migration of red sea cucumbers into deeper water in an association with the seasonal atrophy of the viscera. During the fall, red sea cucumbers may undergo an annual atrophy of the viscera, followed by a period of torpor (Fankboner and Cameron 1985). Dybas and Fankboner (1986) suggested that seasonal atrophy was a survival mechanism triggered by the movement of gut

bacteria into the coelomic cavity. This seasonal visceral atrophy may also be a consequence of diminished food supplies (Fankboner and Cameron 1985). Little is known of the migratory movements of *P. californicus*. Da Silva et al. (1986) found that, in general, short term (less than 50 days) movement patterns of *P. californicus* on horizontal substrates appeared to be random. However, shallow subtidal densities of another sea cucumber species, *P. parvimensis* (Clark), were shown to decline during September and October, which may have resulted from a net movement of animals into deeper water (Muscat 1982, 1983). Our density surveys results from Sheep and Griffin Pass do not substantiate this phenomenon since only two points in time were examined (Table 2) and additional work would be necessary to determine whether seasonal movement occur outside of the sampled time periods. Also, most of the specimens collected during fall surveys lacked viscera, but there were still high densities of sea cucumbers in shallow subtidal habitats suggesting no net movement of sea cucumbers into deeper waters had occurred during visceral atrophy, at least by late September, 1993 (Table 2).

There was a strong relationship between red sea cucumber density and substrate type. Sea cucumbers occurred more frequently on hard complex substrates than soft substrates, and were virtually absent in shallow muddy substrates. Other studies have also reported higher *P. californicus* densities on rocky substrates compared to soft substrates (Zhou and Shirley 1996, Bradbury et al. 1998). Sea cucumbers are thought to prefer soft substrates that are rich in organics, however, this study suggested soft substrates are the least preferred. Evidence suggests that some species of holothurians show directional movement patterns in relation to food supply (Hammond 1982). Therefore, this affinity towards certain substrate types may reflect a localized abundance of food in these habitats. A complex habitat (e.g., crevasses and boulders) may create micro-environments which promote the deposition of detrital material, thus attracting sea cucumbers. Commercial exploitation of red sea cucumbers typically has occurred on soft substrates in B.C. and this preferential exploitation could have depleted populations in these habitats. Fisheries log book data indicated minimal harvest occurred in the surveyed areas, therefore, preferential exploitation is unlikely responsible for the low densities found on soft substrates.

The presence of large numbers of sea cucumbers in shallow subtidal habitats may also be attributed to localize increases in food availability. Leafy kelps are more abundant in shallow, and this may increase habitat complexity and also promote the deposition of organics from the water column. In addition, kelps may be a direct food source through decomposition. The absence of *P. californicus* in areas of large fresh water input suggested sea cucumbers were unable to tolerate reduced salinities. Similar findings occurred in New Zealand where sea cucumber (*Stichopus mollis*) mortality may have resulted from reduced salinity (Mladenov and Campbell 1998).

Little is known about the distribution, abundance and population dynamics of *P. californicus* at depths greater than 15 m in B.C. Individual *P. californicus* have been observed as deep as 181 m in Tasu Sound, Queen Charlotte Islands, B.C. (Lambert 1986), 249 m (McEuen 1987), and about 180 m in Barlow Cove, southeast Alaska (Zhou and Shirley 1996). Future sampling of *P. californicus* at depths greater than 15 m, preferably should use remote sensing devices (e.g., a ROV) (Bradbury et al. 1998) to obtain information on deep water sea cucumber stocks in B.C.

Future stock assessment of *P. californicus* in B.C. should continue obtaining information on biomass, seasonal movement patterns, population parameters (e.g., growth, mortality and recruitment rates) to allow estimation of productivity using yield models from local geographic areas. Changes to more optimal management strategies of the *P. californicus* fishery in B.C. are being developed through a phased approach in adaptive experimental management as suggested by Boutillier et al. (1998) and Perry et al. (1999).

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Table 1. Wet weights (g) of sea cucumbers sampled from survey areas. Numbers in brackets next to means are standard errors. N is number of sea cucumbers measured.

Details	Whole Round Weight	Drained Wet Weight: Split	Drained Wet Weight: Skin	Drained Wet Weight: Muscle
Sheep/Griffin Passage 1993-94 (N = 585)				
Mean		207.3 (2.5)		
Minimum		53		
Maximum		454		
Alexander Inlet 1994 (N = 254)				
Mean	893.9 (17.9)	377.2 (6.5)	248.7 (4.5)	105.4 (1.9)
Minimum	208	48	23	23
Maximum	1677	737	496	226
Meyers Passage 1996 (N = 148)				
Mean	831.4 (21.8)	358.5 (8.3)	248.1 (5.8)	96.1 (2.5)
Minimum	256	109	78	30
Maximum	1710	592	454	181
Tolmie Channel 1996 (N = 144)				
Mean	655.2 (21.5)	302.8 (7.7)	206.8 (5.1)	86.6 (2.5)
Minimum	54	26	20	4
Maximum	1460	570	395	171
Green Inlet 1996 (N = 150)				
Mean	365.5 (15.6)	199.4 (6.8)	140.4	51.0
Minimum	94	49	35	12
Maximum	1206	524	366	134

Table 2. Summary of estimated mean split drained weight, mean number per meter of shoreline, and split weight biomass (t) of sea cucumbers during surveys of some fiords in the central coast of British Columbia, 1993-96. CI = 95% confidence interval.

Details	Sheep Passage	Sheep Passage	Griffin Passage	Griffin Passage	Alexander Inlet	Meyers Passage	Tolmie Channel	Green Inlet
Year	1993	1994	1993	1994	1994	1996	1996	1996
Dates	Sept 27- Oct 1	April 24-27	Sept 24-27	April 22-27	Oct 2-7	Aug 20-22	Aug 24-26	Aug. 23
Shoreline length (km)	48.47	48.47	43.95	43.95	22.23	41.76	51.33	15.14
Number of transects	19	21	14	20	49	22	28	9
Mean split weight (g)	207.3	207.3	207.3	207.3	377.2	358.5	302.8	199.4
±SE	2.5	2.5	2.5	2.5	6.5	8.3	7.7	6.8
Bootstrap estimates								
Mean Number / m	18.79	16.71	13.88	13.64	9.71	13.95	20.34	14.62
lower 95 % CI	14.49	12.70	6.29	9.44	7.95	8.30	15.82	8.47
upper 95 % CI	23.35	20.64	23.25	17.94	11.68	21.16	25.21	22.28
Mean total biomass (t)	190.66	167.05	126.67	124.20	81.92	211.36	327.66	46.03
lower 95 % CI	147.04	126.95	57.38	85.95	67.11	125.71	254.89	26.68
upper 95 % CI	237.00	206.35	212.20	163.37	98.54	320.72	406.25	70.16
Mean biomass in t/km	3.93	3.45	2.88	2.83	3.69	5.06	6.38	3.04
lower 95 % CI	3.03	2.62	1.31	1.96	3.02	3.01	4.97	1.76
upper 95 % CI	4.89	4.26	4.83	3.72	4.43	7.68	7.91	4.63

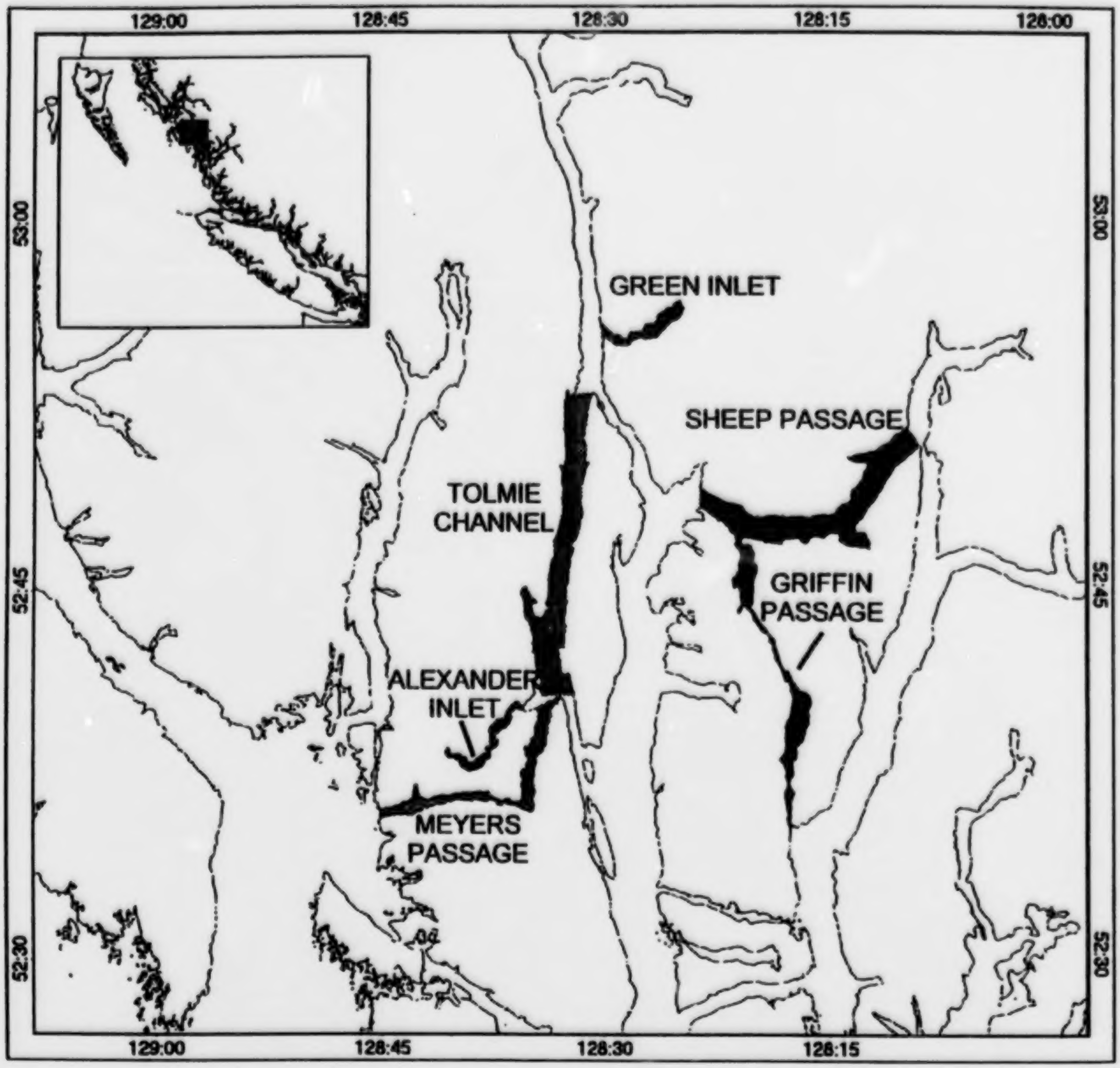

Fig. 1. Shaded areas showing the inlets and passages surveyed for the red sea cucumber, *Parastichopus californicus*, in British Columbia. Inset shows general location (black square) of enlarged area in British Columbia.

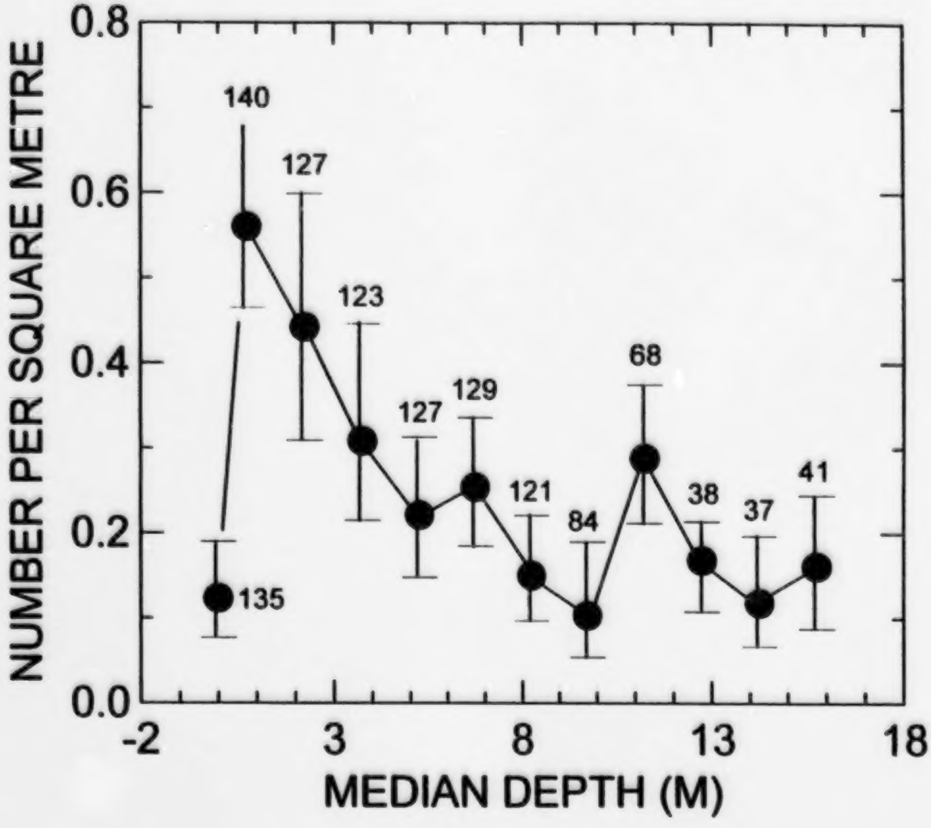

Fig. 2. Estimated mean densities (number/m^2), by 1.5 metre depth intervals, for all sites combined. Vertical lines represent approximate 95% confidence intervals. Values above confidence intervals represent the number of transects that contained data for each depth interval.

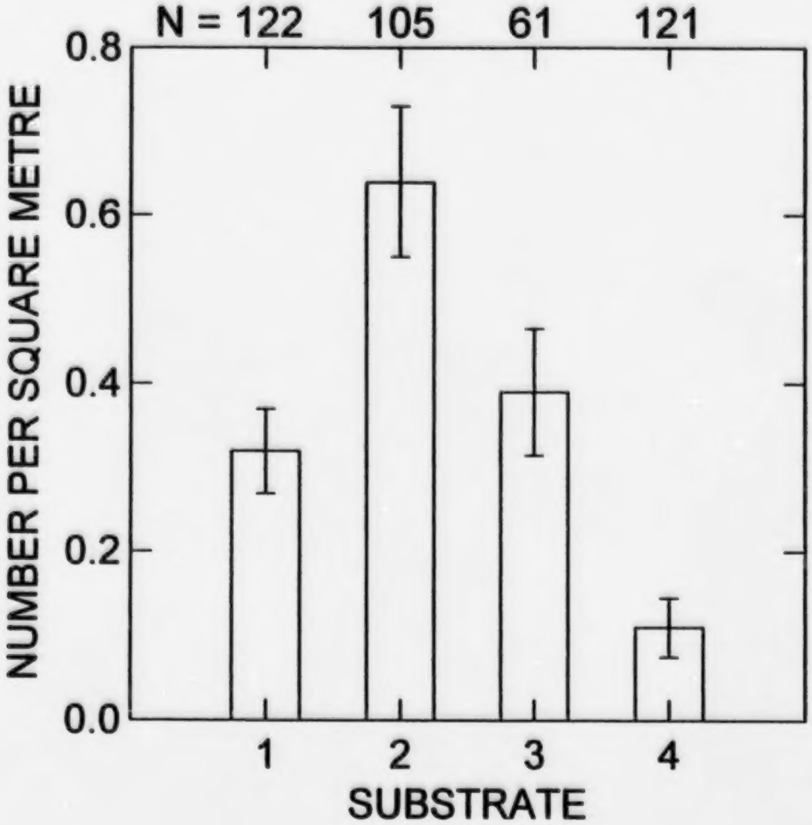

Fig. 3. Estimated mean density (number/m^2) of sea cucumbers by substrate type for all locations combined. Substrate type: 1 = Hard Smooth bedrock; 2 = Complex boulders and Cobble; 3 = Mixed hard and soft substrate with hard substrates dominant; 4 = Mainly soft substrates mixed with some hard substratum. Vertical lines are approximate 95% confidence intervals. N = number of transects that contained each substrate type.